Tetra Tech EM, Inc.

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Evaluation of EcoAggMat Produced from NY/NJ Harbor Sediment

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Submitted by:
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by

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SUMMARY

A sample of EcoAggMat produced from commercial-scale conversion of NY/NJ harbor sediment was received from Tetra Tech EM Inc. for testing and evaluation as an aggregate to partially replace sand in mortars. The material was tested in accordance with a number of ASTM methods that included absorption, density, reactivity, and soundness properties. Mortars made with the blends of ground EcoAggMat (between 16 and 100 mesh) and sand were tested for compressive strength, air-content, and autoclave expansion. The blends tested were of 3:1, 1:1, 0:1 EcoAggMat:sand proportions. As the material was lighter than sand, the blends were made on a volume instead of a weight basis to avoid producing bulky and dry mortars.

Data on EcoAggMat reactivity[2] and soundness were comparable with the ASTM requirements. However, its water absorption was higher than sand because of the porous nature of the material. Data on mortars prepared with 1:1 EcoAggMat-sand blend such as, air-content and autoclave expansion were comparable to those obtained with mortars made with sand only. Their compressive strengths were marginally lower but appeared comparable with those of mortars prepared with sand only. With increasing EcoAggMat addition, the strength decreased.

However, it is noteworthy that, since the EcoAggMat is lighter in weight than the sand, the 28-day strength to weight ratio of mortars produced with 1:1 EcoAggMat:sand blend was higher than the mortar produced with sand only. This property of the EcoAggMat may be of some consideration if the material is to be used in lightweight applications. ASTM C 330 tests may be required to evaluate EcoAggMat as a lightweight aggregate in concrete. Furthermore, because of its porous nature, the EcoAggMat might also have intrinsic insulation properties for diversified applications in construction. Additional testing in this regard is also suggested.

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[2] The test was conducted on a modified ASTM C289, as the standard procedure did not allow extraction of sufficient solution to proceed with testing.

It may also be pointed out that the fraction finer than 100-mesh, being too fine to be used as sand replacement, was removed from the EcoAggMat, while the fraction coarser than 16-mesh was ground and included in the material for mortar tests. The fraction finer than 100-mesh may be recycled for EcoAggMat production to achieve a 100% material utilization.

Based on the preliminary results above, the 16- to 100-mesh fraction of EcoAggMat may be acceptable as a 50% sand replacement (by volume) in mortars.

INTRODUCTION

This report consists of results obtained from the characterization and evaluation of EcoAggMat sample submitted to CTLGroup by Tetra Tech EM Inc. The EcoAggMat was produced from NY/NJ harbor sediment during a commercial-scale demonstration of GTI's Cement-Lock® technology. The Cement-Lock® technology employs pyro-processing of carefully proportioned blends of the sediment with other ingredients to inertize contaminations in the sediment while producing marketable products that are usable in construction applications. Furthermore, the organic compounds in the sediments are reportedly destroyed and converted to innocuous carbon dioxide and water during the pyro-processing of the material (Rehmat and others, 1998).

CHARACTERIZATION OF EcoAggMat

The as-received EcoAggMat sample was wet, coarse-grained, and lumpy material (Figure 1). The material was friable, but because of prolonged sitting, appeared to have set (hardened into lumps) most likely due to lime-rich conditions, and needed to be broken to smaller pieces prior to drying (Figure 2).

Figure 1. As-received EcoAggMat was wet and consisted of large lumps

Figure 2. EcoAggMat lumps were broken to smaller pieces before drying

MOISTURE CONTENT: ASTM C 566

The as-received EcoAggMat, after breaking into smaller loose pieces, was spread in large metal trays and placed in an oven at 100 ± 5°C to constant mass in order to determine the percentage of evaporable moisture. The weight loss was recorded and the as-derived moisture content was determined to be 30.1%.

PARTICLE SIZE ANALYSIS: ASTM C 136

A representative portion of the dried EcoAggMat was screened through a set of sieves to determine particle size distribution. Sieving was continued for sufficient time so that not more than 1% of the residue on any individual sieve passed during one min. of continuous hand sieving. The size distribution data is shown in Table 1; samples from various size fractions are also shown in Figure 3.

Table 1. Particle size distribution of as-received EcoAggMat

ASTM Mesh Size	Amount Retained, Wt. %	Cumulative
4	12.79	12.79
8	13.20	25.99
16	17.52	43.51
30	19.54	63.05
50	16.29	79.34
100	7.16	86.50
Passing 100	13.50	100.00

Figure 3. Various size fractions of EcoAggMat collected during sieve analysis

The average size of the as-received EcoAggMat was between 16 to 30 mesh, somewhat coarser than the standard sand used for mortar testing. Since, the EcoAggMat fraction finer than 100-mesh was too fine for use as sand replacement, it was removed from the material, and tests were conducted on the fraction coarser than 100-mesh.

SPECIFIC GRAVITY: ASTM C 128

A representative sample of the dried EcoAggMat coarser than 100-mesh was tested for specific gravity. The material was subdivided into “coarser than 4-mesh” and “between 4- and 100-mesh” fractions. The specific gravities of both the fractions were measured in accordance with the ASTM C 128 procedure. The subdivision was made with the intention that, at some point, material coarser than 4-mesh might be considered for coarse aggregate applications. Their specific gravities and that of the composite are shown in Table 2.

Table 2. Specific gravity determination of EcoAggMat

ASTM, Mesh Size	Amount Retained, g	%	Specific Gravity
4	12.79	14.79	1.42
8			
16			
30			
50			
100	73.71	85.21	1.93
Composite	86.50	100.00	1.85

The specific gravity of the composite (1.85) is notably lower than the sand (2.65) - because the material is of porous nature (Figure 4). It may also be noted that the specific gravity of material coarser than 4-mesh is lower than that of the minus 4 to + 100 mesh.

WATER ABSORPTION: ASTM C 128

Since the material is porous in nature (Figure 4), it was decided to determine its water absorption. This would also reflect on the water requirement of material when used in mortars. The absorption of EcoAggMat was calculated on the basis of water absorbed in the pores within the material when, compared to dry condition, the material was submerged in water long enough to satisfy its absorption potential.

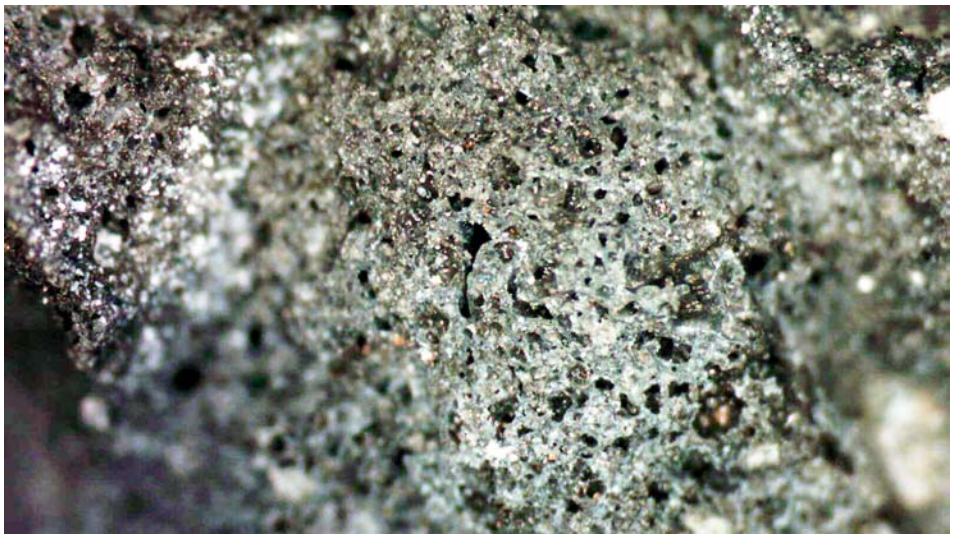

Figure 4. EcoAggMat showing distribution of pores (Field length ≈ 2 mm)

Known amounts of EcoAggMat factions were oven dried to constant mass, cooled to room temperature, and submerged in water for 24 hours. Thereafter, water was decanted and the material spread on a nonabsorbent surface to a gentle current of warm air until the saturated surface-dry (SSD) condition is reached. Absorption was calculated from the weight difference between the original dry and SSD materials. The data are given in Table 3.

Table 3. Absorption measurement of EcoAggMat

ASTM, Mesh Size	Amount Retained, g	%	Absorption, %
4	12.79	14.79	2.08
8			
16			
30			
50			
100	73.71	85.21	13.57
Composite	86.50	100.00	15.64

A 15.64%, absorption of the composite is significantly higher than sand (< 0.5%); sand is virtually nonabsorbent. This can result in higher water demand for EcoAggMat when using as a partial replacement for “sand” in mortars.

REACTIVITY: ASTM C 289

This test determines the potential reactivity of the material as indicated by the amount of reaction with NaOH solution. A representative portion of the dried EcoAggMat was ground to between 50 and 100 mesh and subjected to the test. The reaction procedure was performed according to a modified ASTM C 289 in which 12.5 g sample was used with 25 ml NaOH versus the test standard 25 g sample with 25 ml NaOH. A 1:1 solid to solution ratio did not allow sufficient solution to be extracted for testing apparently due to absorption.

The results show EcoAggMat to be innocuous (non-reactive). Additional tests may be needed to confirm this.

SOUNDNESS: ASTM C 88

This test determines the soundness of EcoAggMat when subjected to a weathering action by repeated immersion in saturated solution of sodium sulfate or magnesium sulfate. Fifty grams each of the fractions between 4- and 50-mesh of the dried EcoAggMat material were tested by repeatedly immersing in a saturated solution of magnesium sulfate. Soundness tests on fine aggregates do not use material coarser than 4- and finer than 50-mesh. Samples were repeatedly immersed overnight, drained, washed and re-immersed for a period of one week. The amount of weathered material in each fraction was recorded as weight loss to determine the degree of soundness. Results are shown in Table 4.

Table 4. Data on EcoAggMat soundness test

ASTM Mesh Size	Grading of Sample, %	Amount Used, g	Amount Passed, After Test	Loss, Wt. %	Loss, Weighted Basis, %
Coarser than No. 8	12.79	-	-	-	-
No. 4 to No. 8	13.20	50.19	0.2	0.40	0.05
No. 8 to No. 16	17.52	50.29	2.2	4.40	0.77
No. 16 to No. 30	19.54	50.20	5.95	11.90	2.33
No. 30 to No. 50	16.29	50.20	9.4	18.80	3.06
No. 50 to No. 100	7.16	-	-	-	-
Composite	86.50				6.21

The soundness data on the EcoAggMat fractions are well below the specified maximum limit of 15% for fine aggregates tested in magnesium sulfate solution.

PREPARATION OF EcoAggMat – OTTAWA SAND BLENDS

In order to test and evaluate EcoAggMat as a partial replacement of sand in mortars, a bulk quantity of EcoAggAMat was prepared in the laboratory. EcoAggMat fraction coarser than 16-mesh was crushed and sieved to obtain a sufficient quantity of material retained in the minus16 to + 100 size fraction (Figure 5).

Figure 5. The minus 16 to + 100 size fraction of EcoAggMat prepared for testing

The material was then blended with standard Ottawa sand at 3:1 and 1:1 volumetric ratios, to prepare EcoAggMat:sand blends, as shown in Table 5. Volumetric instead of weight proportions were used because the material was lighter than the sand (SG. 1.85 vs. 2.65) that could result in bulkier and drier mortar than the one normally produced.

Table 5. Preparation of EcoAggMat-Ottawa Sand Blends

EcoAggMat:Ottawa Sand Blend	EcoAggMat, Vol. %	Ottawa Sand, Vol. %
3:1	75	25
1:1	50	50
0:1 (Control)	0	100

TESTING AND EVALUATION OF EcoAggMat – OTTAWA SAND BLENDS

The EcoAggMat-Ottawa sand blends were subjected to a number of tests to evaluate its viability as an aggregate for mortars. The tests included autoclaving, air content, and compressive strength determinations.

AUTOCLAVE EXPANSION: ASTM C 151

This was a modified ASTM C 151 test in which mortars bars were prepared using the EcoAggMat:sand blends and comparing the results with mortar bars made with sand only. Typically, ASTM C 151 test is for cement only, however, since the EcoAggMat was rich in lime, the aim was to determine whether it would adversely impact the expansion when used in mortars and autoclaved.

Mortar bars were prepared by using Type I/II portland cement and EcoAggMat:sand blends as per the ASTM C 151 procedure. The mortars were cast as 1 x 1 x 10-in bars and cured overnight. The bars were demolded, measured for length and then placed in the autoclave (high pressure steam vessel) for 3 hours (Figure 6a). Thereafter, the bars were brought to room temperature, taken out of the autoclave (Figure 6b), and measured for expansion using a comparator. The percentage increase in length is reported to the nearest 0.01%.

a.  b. 

Figure 6. EcoAggMat:sand mortar bars in autoclave expansion test

Tests were done on replicate samples and data compared with control mortar made with sand only (0:1 blend, control). The results are shown in Table 6:

Table 6. Autoclave expansion data on EcoAggMat:sand mortars

EcoAggMat:Sand Blends	Initial	Final	Autoclave Expansion, %	Average, %
3:1 (reading 1)	0.058	0.068	0.10	
3:1 (reading 2)	0.017	0.027	0.10	
3:1 (reading 3)	0.055	0.065	0.10	0.10
1:1 (reading 1)	0.060	0.069	0.09	
1:1 (reading 2)	0.058	0.067	0.09	
1:1 (reading 3)	0.060	0.069	0.09	0.09
0:1 Control (reading 1)	0.049	0.056	0.07	
0:1 Control (reading 2)	0.048	0.055	0.07	0.07

There is no significance expansion of mortar bars made with the EcoAggMat:sand blends. In fact, their values of 0.10% and 0.09% were comparable to 0.07% for mortars made with sand only (0:1 blend, control). ASTM C150[3] allows a maximum of 0.8% expansion for 1 x 1 x 10-in bars made with Type I/II cement.

[3] ASTM C 150 is a cement specification referred here for convenience to compare expansion of mortars made with sand (0:1 blend, control) versus EcoAggMat:sand blends.

AIR-CONTENT: ASTM C 185

The EcoAggMat were used to determine the air-content in mortars when used as a partial replacement of sand. Since the material was pervious in nature, the aim was to determine how it would impact the air-content of a mortar. The air-content tests were carried out per ASTM 185 procedure. Mortars were prepared using the same EcoAggMat:sand blends as above and the air-content data compared with mortars prepared with sand only. Mortars were made using water content sufficient to attain a specified flow of 87.5 ± 7.5. The mortars were then compacted in cup of known volume and weighed. The air content is calculated as per the calculations specified in ASTM 185. The results are in Table 7 below.

Table 7. Air-content data of EcoAggMat:Sand mortars

EcoAggMat:Sand Blend	% Air, Using Actual EcoAggMat Density
3:1	5.5
1:1	5.2
0:1 (Control)	9.1

The air contents of 5.5% and 5.2 % for EcoAggMat mortars were significantly lower than 9.1% for sand-only mortars (0:1 blend, control). ASTM C150[4] allows a maximum of 12% air content for Type I/II cement mortars made with sand only.

COMPRESSIVE STRENGTH: ASTM C 109

The same blends as above were used for preparing mortar cubes for compressive strengths. Mortar batches were prepared in accordance with the ASTM C 109 standard mixing procedure. Deionized water was added to adjust mortar consistency to a consistent flow of 110 ± 5. The mortars were cast in triplicates as 2-inch cubes (Figure 7), and left overnight in a moist room at ambient temperature. Thereafter, the cubes were demolded and cured in saturated lime-water solution.

[4] ASTM C 150 is a cement specification referred here for convenience to compare air-content of mortars made with sand (0:1 blend, control) versus EcoAggMat:sand blends.

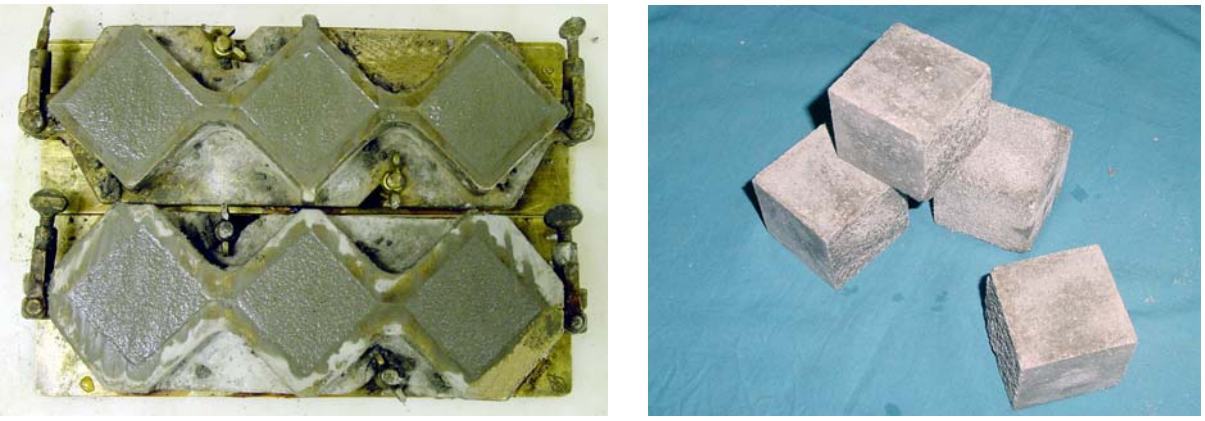

Figure 7. 2-inch EcoAggMat:Sand mortar cubes prepared for strength testing

The cubes were tested for compressive strength after 3, 7, and 28 days of curing. Three cubes were tested at each age and the average value was recorded. The data are summarized in Table 8; the data also include water requirement and flow recorded when preparing mortars.

Table 8. Compressive strength of EcoAggMat:Sand mortars

Test Periods	Sample 1 Strength, psi	Sample 2 Strength, psi	Sample 3 Strength, psi	Average Strength, psi	Average Sample Weight, g	Strength to Weight Ratio
3:1 Blend, Flow = 109; Water Required = 520 ml						
3-day	2083	2043	2088	2070	250	8.28
7-day	2908	2873	2793	2860	253	11.39
28-day	3540	3290	3800	3540	255	13.88
1:1 Blend, Flow = 113; Water Required = 459 ml						
3-day	2430	2280	2380	2360	265	8.91
7-day	3370	3430	3405	3400	264	12.88
28-day	4420	4620	4420	4490	267	16.75
0:1 Blend (Control), Flow = 115; Water Required = 359 ml						
3-day	3070	2900	2770	2910	287	10.14
7-day	4190	4270	4210	4220	287	14.76
28-day	4680	4760	5110	4850	291	16.67

Water requirement for producing mortars with 110 ± 5 flow with EcoAggMat is greater than the control. The water demand increased with increasing EcoAggMat addition. This is attributed to the porosity of the EcoAggMat and the ensuing increased absorption.

The data indicate that the strength of mortars made with Ecomelt:sand blends increased with curing time, similar to the mortars made with sand only. The 1:1 EcoAggMat:sand mortars acquired lower, yet comparable, 3-, 7-, and 28-day strengths to the sand only mortars. The strength decreases with increasing EcoAggMat addition. ASTM C150[5] requires minimum 3-, 7-, and 28-day strengths of 1740, 2760, and 4060 psi, respectively, for Type I cement mortars made with sand only.

However, it may be noted that the 28-day strength to weight ratio of 1:1 EcoAggMat:sand mortar was higher than the mortar prepared with sand. This is because the specific gravity of EcoAggMat is lower than the sand (1.85 vs. 2.65). This may be of some consideration if the material is to be used in lightweight aggregate applications.

CONCLUSIONS AND RECOMMENDATIONS

Data indicate that the EcoAggMat produced by converting NY/NJ harbor sediment complied with the physical tests for reactivity and soundness. The absorption of EcoAggMat was, however, higher than the sand which translated in higher water demand when preparing mortars. The other physical data on mortars prepared from EcoAggMat:sand blends, such as air-content and autoclave expansion, complied with the ASTM requirements.

The mortars prepared with 1:1 EcoAggMat-sand blend exhibited somewhat reduced, yet comparable, strength data to mortars prepared with sand only. Strength decreased with increasing EcoAggMat addition. However, since the EcoAggMat is a low-density material, the 28-day strength to weight ratio of mortars produced with 1:1 EcoAggMat:sand blend was higher than the mortar prepared with sand only. This is a useful criterion if the material is to be considered for lightweight applications. Selected ASTM C 330 tests may be required to evaluate EcoAggMat as lightweight aggregate in concrete. Additionally, because of its porous nature, the EcoAggMat might have insulation properties for diversified material applications. Additional tests in this regard are also suggested.

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[5] ASTM C 150 is a cement specification. The strength values are referred here for convenience to compare strength of mortars made with sand (0:1 blend, control) versus EcoAggMat:sand blends.

Based on the preliminary results above, the 16- to 100-mesh fraction of EcoAggMat may be acceptable as a 50% sand replacement (by volume) in mortars.

Finally, in order to optimize the use of the EcoAggMat, the fraction finer than 100-mesh may be removed and recycled into raw feed for EcoAggMat production; whereas the fraction coarser than 4-mesh is ground and included in the test material. This will achieve a 100% material utilization.

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